PERIOD CHANGES IN SIX CONTACT BINARIES: WZ AND, V803 AQL, DF HYA, PY LYR, FZ ORI, AND AH TAU

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ABSTRACT

Six contact binaries lacking a period analysis have been chosen to search for the presence of a third body. The $O-C$ diagrams of these binaries were analyzed with the least-squares method by using all available times of minima. Ten new minima times, obtained from our observations, were included in the present research. The Light-Time Effect was adopted for the first time as the main cause for the detailed description of the long-term period changes. Third bodies were found with orbital periods from 49 up to 100 years, and eccentricities from 0.0 to 0.56 for the selected binaries. In one case (WZ And) a fourth-body LITE variation was also applied. The mass functions and the minimal masses of such bodies were also calculated and a possible angular separation and magnitude differences were discussed for a prospective interferometric discovery of these bodies.

Keywords: stars: binaries: eclipsing – stars: individual: WZ And, V803 Aql, DF Hya, PY Lyr, FZ Ori, AH Tau – stars: fundamental parameters

1. INTRODUCTION

Eclipsing Binaries (hereafter EBs) are excellent objects for determining the physical properties of stars and detecting additional components in them. The long-time behavior of the period of an EB could reveal the presence of another component orbiting with the EB around the common center of mass. Photometric observations of EBs sometimes cover more than a century, therefore it is possible to detect the third bodies with a similar period.

The motion around the barycenter causes apparent changes of the observed binary's period with a period corresponding to the orbital one of the third body, called the LIght-Time Effect (or 'light-travel time', hereafter LITE). Irwin (1959) improved the method developed by Woltjer (1922) for analyzing the long-term variation of the times of minima caused by a third body orbiting the eclipsing pair. Useful comments and limitations were discussed by Frieboes-Conde & Herczeg (1973) and by Mayer (1990). Nowadays there are more than one hundred EBs showing LITE, where the effect is certainly presented or supposed (see

e.g. Borkovits & Hegedüs (1996), Albayrak et al. (1999), Wolf et al. (2004), Hoffman et al. (2006), etc.). See the catalogue of the $O-C$ diagrams by Kreiner et al. (2001), where the apparent orbital period changes in many EBs are presented. The look of $O-C$ diagrams in the present study was adopted to be the same as in this catalogue. In our figures 1 to 8 the full circles represent the primary and the open circles the secondary times of minima, the bigger the point, the bigger the weight. For the limitations and consequences of the $O-C$ diagram analysis, see e.g. Sterken (2005).

The computation of the parameters of the third-body orbit is a classical inverse problem with 5 parameters to be found – p_3, T_0, A, ω, e_3, which indicate the period of the third body, the periastron passage, the semi-amplitude of the light-time effect, the argument of periastron and the eccentricity, respectively (for a detailed description see e.g. Mayer 1990). The ephemerides for the individual systems (JD_0 and P for the linear one and q for the quadratic one) have to be calculated together with the parameters of LITE. The mass function $f(M_3)$ and the minimal mass of the third component $M_{3,min} = M_3 \cdot \sin i_3$ (for $i_3 = 90°$) could be computed

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from this set of parameters. The weights assigned to individual observations were used as following: $w = 1$ for visual observations, 3-5 for photographic and 10 for CCD and photoelectric observations. The computing code, used in the present work, could be downloaded via the webpages of the author[1].

The present study was carried out following a similar analysis of period changes in Algol-type binaries (made by Zasche et al. 2008). All the systems selected for this paper are contact EBs, of W UMa or β Lyr type, with components of similar spectral types (ranging from F to K). Except for a few new observations given in Table 1, all the times of minima used in this paper were collected from the published literature and from minima databases available in the internet.

According to a recent paper on the period changes in Algols by Hoffman et al. (2006), there could be a connection between the spectral type of the secondary component and the nature of the period changes. Systems with spectral types of secondaries later than F5 show $O - C$ variations, which could be caused by magnetic activity cycles and convective envelopes. This effect was discussed by Hall (1989), Applegate (1992), Lanza et al. (1998), etc. The role of the magnetic cycles in the period changes is discussed below, but, due to lack of information about the systems, such an analysis is a difficult task. For some of the systems studied in this paper the spectral types of the secondaries are known with a low confidence level, light-curve analysis is missing and spectroscopy has never been done.

<div align="center">

TABLE 1
New times of minima based on CCD observations (Kwee-van Woerden (1956) method was used).

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Star	HJD-2400000	Error	Type	Filter
DF Hya	54189.34526	0.00018	II	R
DF Hya	54210.33806	0.00005	I	R
FZ Ori	54099.45835	0.00019	II	R
FZ Ori	54102.45888	0.00006	I	R
FZ Ori	54109.45926	0.00008	II	R
FZ Ori	54535.24562	0.00012	I	VR
AH Tau	54099.32718	0.00006	II	R
AH Tau	54115.29518	0.00004	II	R
PY Lyr	54564.55117	0.00021	I	R
PY Lyr	54592.51913	0.00017	II	R

2. OBSERVATIONS

The new measurements were secured at the Athens University observatory, which is situated at Athens University campus, Athens, Greece. The 40-cm telescope is equipped with the SBIG ST-8XMEI CCD camera and the Bessell UBVRI photometric filters. All of the observations were obtained from December of 2006 to April 2008. The exposure times depend on the individual systems and observing conditions, ranging from 25 to 80 seconds.

3. ANALYSIS OF INDIVIDUAL SYSTEMS

3.1. *WZ And*

The first analyzed system is the eclipsing binary WZ And (GSC 02799-01250). This β Lyrae system is

about 11.6 mag bright in V filter (Kukarkin et al. 1971) and its spectrum was classified as F5 + G3 (according to Rafert 1982). It was discovered to be a variable by Miss Leavitt, see Shapley (1923), and its eclipsing nature was confirmed by Zessewitsch (1925). The most recent detailed analysis of the light curve of this system was made by Zhang & Zhang (2006), which indicates that the system is in a shallow contact and has the photometric mass ratio about 1. Regrettably, the radial velocity curve has not been obtained so far.
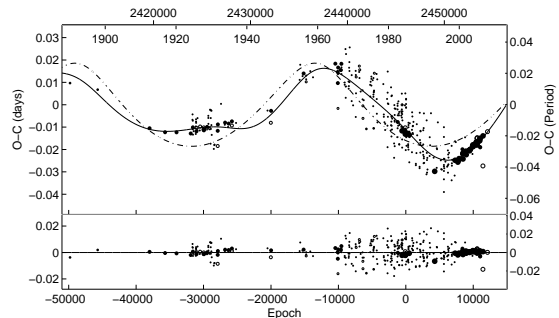

FIG. 1.— The $O-C$ diagram of WZ And. The individual observations are shown as dots (primary minima) and open circles (secondary minima), the small ones for visual and the large ones for CCD and photoelectric observations, the bigger the symbol, the bigger the weight. The dash-dotted curve represents the predicted LITE variation caused by the third body, while the solid line represents the final fit (the third and the fourth body, see the text for details). The residuals after the fit are in the bottom part of the figure. For the variation caused by the fourth body only see Fig.2.

The first minima observations are more than a century old. Altogether there are about 400 minima, but for the current analysis 37 of them were neglected due to their large scatter. The previous period analysis of this system was performed by Zhang & Zhang (2006), who suggested a few period jumps and mass transfer between the two components. They were not able to fit a sinusoidal curve to those data, because the period variation is more complicated. Also the previous analyses by Oh (1991) and Rafert (1982) presented a quadratic ephemeris to describe the variation in the $O - C$ diagram.

With the new larger data set, one is able to identify a double variation in the $O-C$ diagram, where the first one is caused by a third and the second one by a fourth body in the system (see Fig.1 for the plot of the $O-C$ diagram with the final fit). The $O-C$ variation, due only to the fourth body is given in Fig.2. These variations have a period of about 70 and 50 years respectively and their parameters are given in Table 2.

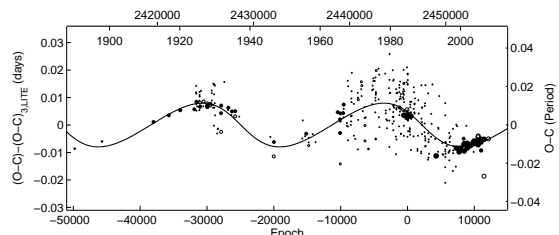The total mass of the binary is $M_{12} = 2.27$ M$_\odot$ (ac-

FIG. 2.— The $O - C$ diagram of WZ And after subtraction of the variation caused by the third body. The solid line represents the predicted variation caused by a fourth body only.

cording to Cook 1948). Using this mass, one could calculate the mass function and the minimal masses of the third and also the fourth component (see Table 2). These masses, assuming that the additional components belong to the MS, indicate their spectral types should be about M3 and M5, respectively. Their contribution to the total light is negligible (below 1%), but in the red part of the spectrum could be detectable. The distance of this system is about 440 pc (Shaw 1994), so the predicted angular separation and the magnitude difference between the additional components and the EB can also be estimated. The angular separation results in 52 and 45 mas, respectively, which is well within the limits for a detection by modern stellar interferometers. On the other hand, due to their relatively low masses (and therefore also their luminosities), the magnitude differences between them and the EB result in high values about 5 mag for the third and 6 mag for the fourth component. Such large magnitude differences make extremely difficult the discovery of such distant components.

If there are more than 3 components in the system, then a question arises not only about the dynamical stability of such a system, but also about the suitability of the period analysis to find such bodies. The method of LITE itself was derived on the basis of von Zeipel's method for the three-body problem, where the assumption that the third body is far away from the eclipsing pair does play the main role. This condition in the present case is not satisfied, so it is problematic to judge whether this method could be used for such an analysis.

3.2. V803 Aql

The EB system V803 Aql is a neglected W UMa-type system, with an orbital period about 0.3 days and a depth of both primary and secondary minima about 0.8 mag. It is relatively faint binary, only about 14 mag in V filter and the spectral types of the components were found to range between K3 to K5 (see Samec et al. 1993). The only detailed analysis of its light curve was made by Samec et al. (1993), who derived that both components are very similar to each other, but also proposed a possible explanation of its period changes due to the mass loss from the system caused by a stellar wind.

The new set of times of minima comprises 150 data points, from which 4 visual ones were neglected due to their large scatter. The six minima times from Samec et al. (1993) were corrected for their heliocentric correction and fit better the theoretical curve of the LITE
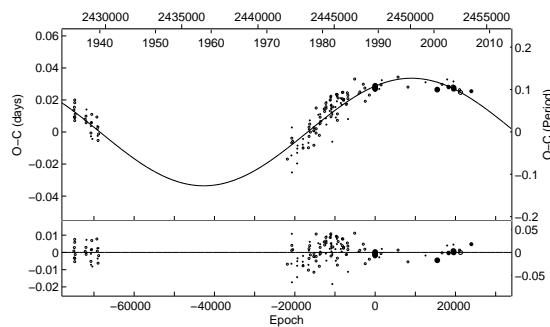
variation (see Fig.3). Such a variation is caused by a third body orbiting about the EB pair on its 75 yr circular orbit. The parameters of the orbit are given in Table 3, and these values yielded a third-body mass about $0.5\ M_\odot$. With the assumption that the third component is a main sequence star, one gets its spectral type about K8. Such a body could be detectable in the light curve analysis, as well as in the spectra of the system. Regrettably, no spectral analysis has been performed so far and Samec et al. (1993) did not include the third light parameter in their light curve analysis.

Despite the fact that the distance of the system is not known, one can estimate a photometric parallax of V803 Aql on the basis of its spectral type and luminosity. The distance is therefore about 300 pc, from which one could estimate the predicted angular separation of the third component to be 75 mas and its magnitude difference about 2 mag. Such values allow for the discovery of the 3rd body using modern interferometric technique.

3.3. DF Hya

Another EB showing period changes is the system DF Hya (AN 343.1934).It is about 10.7 mag bright in V filter, it has an orbital period about 0.3 days and belongs in the W UMa-type systems. It was discovered as a variable star by Hoffmeister (1934), who classified the system as a short-period variable star. The most recent detailed analysis of its light curve was published by Niarchos et al. (1992), who also derived its basic physical properties. Due to the asymmetric shape of its light curve, both primary and secondary components were found to have magnetic spots and the spectral type of the system was assumed to be G0V. The basic physical parameters of the system derived by Niarchos et al. (1992) are comparable with those derived by Liu et al. (1990).

As an explanation of the period changes in this system, all the previous period analyses proposed a mass transfer between the two components (Zhang et al. 1989), or abrupt period jumps (Srivastava 1991). With the new set of up-to-date times of minima, counting altogether 143 data points, one is able to identify the long-term variation to be periodic instead of the steady increase caused by a mass transfer. Especially, the new data points after the year 2000 evidently deviate from the quadratic ephemeris (see Fig.4). The parameters of the LITE are given in Table 3, the final fit is given in Fig.4 and the predicted third-body's minimal mass results in $0.84\ M_\odot$.
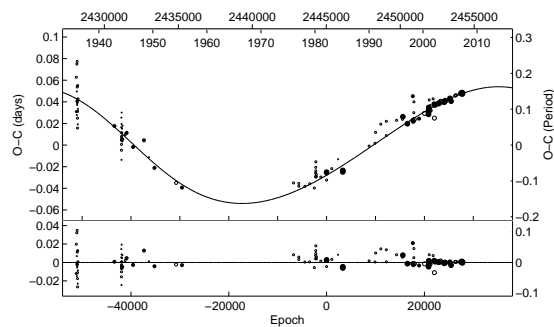

FIG. 3.— The $O-C$ diagram of V803 Aql (upper part), where the solid line represents the theoretical LITE variation caused by a 3rd body and the $O-C$ residuals obtained after the subtraction of LITE (lower part). For the explanation of symbols see Fig.1.

FIG. 4.— The $O-C$ diagram of DF Hya (upper part), where the solid line represents the theoretical LITE variation caused by a 3rd body and the $O-C$ residuals obtained after the subtraction of LITE (lower part). For the explanation of symbols see Fig.1.

TABLE 2
The final results (part 1): The parameters of the LITE orbits derived from the $O - C$ analysis. The table is divided into two parts. In the first one, the computed parameters are presented, while in the second one the derived quantities are given (the mass $M_{12} = M_1 + M_2$ and the distance d are taken from the literature).

Parameter	WZ And		V803 Aql	DF Hya
	3rd body	4rd body		
JD_0 [HJD]	2446025.734 ± 0.002		2447684.785 ± 0.003	2445021.531 ± 0.004
P [day]	0.6956612 ± 0.0000001		0.2634232 ± 0.0000001	0.3306022 ± 0.0000003
p_3 [yr]	67.8 ± 4.1	51.7 ± 4.3	74.6 ± 3.1	86.3 ± 14.2
T_0 [HJD]	2437000 ± 2400	2447500 ± 2700	–	2430920 ± 8000
ω [deg]	98.4 ± 37.5	179 ± 58	–	165 ± 104
e	0.28 ± 0.18	0.23 ± 0.22	0.000 ± 0.110	0.162 ± 0.096
A [day]	0.0186 ± 0.0022	0.0080 ± 0.0024	0.0336 ± 0.0023	0.054 ± 0.009
M_{12} [M$_\odot$]	2.27		1.5	1.45
d [pc]	440		300	190
$f(M_3)$ [M$_\odot$]	0.0073 ± 0.0005	0.0011 ± 0.0003	0.0353 ± 0.0004	0.114 ± 0.003
$M_{3,min}$ [M$_\odot$]	0.37 ± 0.03	0.21 ± 0.04	0.52 ± 0.02	0.84 ± 0.02
a [mas]	52	45	75	150

Assuming the component to be a main-sequence star, then it should be of K1 spectral type and therefore a third light should be considered in the light curve solution. Such a third light was not included in the light curve solution of Niarchos et al. (1992). Using the same method as in the case of V803 Aql, one could also estimate the value of the photometric distance of the additional component resulting in 190 pc, which yields the predicted angular separation of 135 mas and a magnitude difference from the EB of about 1.3 mag. Such a star could be easily detectable with the modern stellar interferometers.

3.4. PY Lyr

The eclipsing binary system PY Lyr (GSC 02136-03365) is of W UMa-type and its magnitude is about 12.5 in B filter. Both primary and secondary minima are about 0.6 mag deep and the orbital period is about 0.4 d. Its spectral type was classified as F0 (Malkov et al. 2006), but it is only a preliminary one.

Precise CCD observations were carried out by Manimanis et al. (2006), but they didn't include the third light into their analysis. The radial velocities have not been measured, but many papers have been published with times of minima. Information about a possible period change is given by Pribulla et al. (2003), who noticed some modulation of its orbital period, but they concluded that this variation is uncertain. On the other hand, Brát (2001) published a paper on PY Lyr, where the period changes were described by two period jumps – near 1967 and 1987.
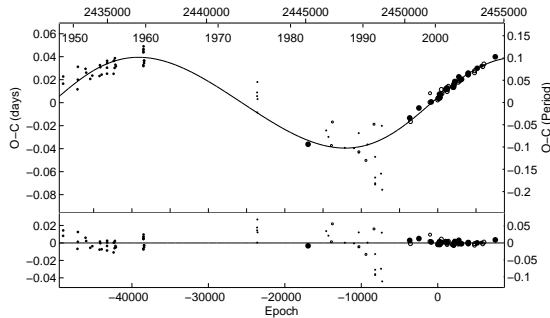

FIG. 5.— The $O - C$ diagram of PY Lyr (upper part), where the solid line represents the theoretical LITE variation caused by a 3rd body and the $O - C$ residuals obtained after the subtraction of LITE (lower part). For the explanation of symbols see Fig.1.

Collecting all the minima times, one gets a set of 123 data points. Fig.5 represents the $O - C$ diagram of all these measurements, where the period variation is clearly visible. A period of about 50 years is now well covered and the resulting parameters of the predicted LITE variation are given in Table 2. Assuming that the mass of the eclipsing pair is about 2.5 M$_\odot$ (according to its spectral type), the minimal mass of the predicted third component results in 1.17 M$_\odot$, which is approximately the same value of mass as the primary and secondary component. Therefore, the third light can be easily detectable in the light curve solution. Regrettably, the parallax and the distance to this system is not known, but it could be estimated using the same method as in the previous case. The value of the system's photometric distance results in 750 pc, therefore the predicted angular separation of the third component is about 29 mas and its magnitude difference from the EB is about 1.3 mag. Such a component would be hardly observable interferometrically.

The photometric data obtained by one of us (V.M.), we reanalysed again by taking into consideration the third body's contribution to the total light of the system. The software PHOEBE 0.29d, which is based on the Wilson-Devinney code, was used in order to extract the new model of the system. B, V, R, and I observations of this system were analyzed (see Fig.6), yielding a new set of physical parameters given in Table 4, where T_i, L_i, Ω_i, and x_i denote the temperature, the luminosity, the modified Kopal potential, and the limb-darkening coefficients for primary and secondary, respectively. The "mode 3" was used for computing (hence $\Omega_1 = \Omega_2$) and the eccentricity was set to 0 (circular orbit). The value of temperature of the primary component was assumed from its spectral type. The limb-darkening coefficients were interpolated from van Hamme's tables (see van Hamme 1993).
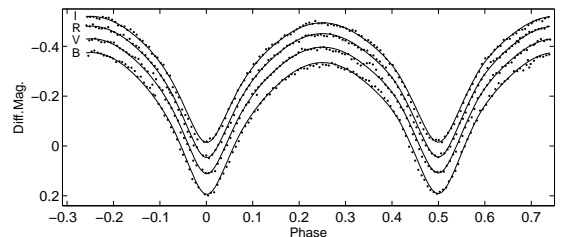

FIG. 6.— The light curves of PY Lyr in B, V, R, and I filters, respectively. The solid lines represent the solution according to the parameters given in Table 4.

TABLE 3
THE FINAL RESULTS (PART 2).

Parameter	PY Lyr	FZ Ori	AH Tau
JD_0 [HJD]	2451663.563 ± 0.005	2450479.403 ± 0.005	2442750.359 ± 0.002
P [day]	0.3857645 ± 0.0000002	0.3999858 ± 0.0000003	0.3326737 ± 0.0000002
p_3 [yr]	52.5 ± 0.9	48.9 ± 2.1	77.6 ± 7.3
T_0 [HJD]	2451360 ± 1780	2450500 ± 460	2443600 ± 1200
ω [deg]	0 ± 34	189.4 ± 8.5	118.1 ± 17.0
e	0.138 ± 0.115	0.559 ± 0.210	0.31 ± 0.12
A [day]	0.0395 ± 0.0023	0.0214 ± 0.0010	0.0319 ± 0.0023
q [day]	–	$(0.31 \pm 0.02) \cdot 10^{-10}$	–
M_{12} [$M_\odot$]	2.5	2.1	1.61
d [pc]	750	250	281
$f(M_3)$ [$M_\odot$]	0.119 ± 0.004	0.036 ± 0.004	0.0289 ± 0.0003
$M_{3,min}$ [$M_\odot$]	1.17 ± 0.04	0.65 ± 0.02	0.51 ± 0.01
a [mas]	29	75	83

TABLE 4
THE LIGHT CURVE PARAMETERS OF PY LYR. THE '*' MARK INDICATES THE ASSUMED VALUE.

			$L_1[\%]$	$L_2[\%]$	$L_3[\%]$	x_1	x_2
T_1[K]	6980^*						
T_2[K]	7042	B	47.0	34.3	18.7	0.607	0.603
i[deg]	80.379	V	46.7	33.8	19.5	0.498	0.495
q	0.6596	R	46.7	33.6	19.7	0.417	0.414
Ω_1	3.018	I	46.1	33.0	20.9	0.339	0.335
Spot parameters:	Latitude[deg]	Longitude[deg]	Radius[deg]	$T_{spot}/T_{surface}$			
	71.9	278.3	18.6	0.798			

The values of gravity brightening and bolometric albedo coefficients were set at their suggested values for convective atmospheres (see Lucy 1968), i.e. $g_1 = g_2 = 0.32$, $A_1 = A_2 = 0.5$. Also the synchronous rotation was assumed for each star ($F_1 = F_2 = 1.0$). A spot in the primary component has been used due to the presence of the O'Connell effect. The contribution of the third light to the total luminosity of the system is significant. Its value from the light curve solution results in approximately $(19.7 \pm 5)\%$. On the other hand, the value predicted according to the LITE variation is about $(23 \pm 5)\%$, so it is in very good agreement with each other.

3.5. FZ Ori

The EB system FZ Ori (HD 288166) has been discovered to be a variable by Hoffmeister (1934). It is a W UMa-type system with an orbital period of about 0.4 days and a brightness of about 10.8 mag in V filter. Its spectral type was estimated as G0 (Kholopov 1985).

The light curve of the star was analyzed a few times in the past, but no one of the analyses has been very detailed. One of them was published by Rukmini et al.
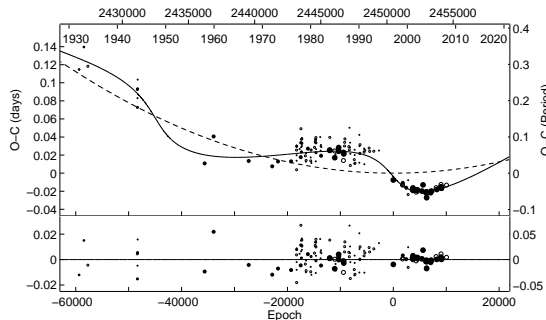

FIG. 7.— The $O - C$ diagram of FZ Ori, (upper part), where the solid line represents the theoretical LITE variation caused by a 3$^{\mathrm{rd}}$ body and the dashed line represents the quadratic ephemeris, and the $O - C$ residuals obtained after the subtraction of LITE (lower part). For the explanation of symbols see Fig.1.

(2001) and the most recent one by Byboth et al. (2004). Both of these studies indicate a slightly asymmetric light curve, which was explained in the latter paper by the presence of a spot on the primary component. A period analysis was performed by Alawy (1993), who also mentioned a possible cyclic changing of the period, but no satisfactory solution was presented.

Our new period analysis is based on a much larger data set, containing 153 times of minima. From these measurements it is possible to identify the steady period increase besides the cyclic variation of its orbital period with a periodicity of about 50 yrs (see Fig.7 for the $O - C$ fit and Table 3 for the final parameters). According to the value of the quadratic-term coefficient, one gets surprisingly high value of conservative mass transfer rate between the components, of about $5.1 \cdot 10^{-7}$ $M_\odot$/yr. A similar result is also presented in Rukmini et al. (2001), where the authors deduce that the system is now in the stage of mass transfer. Assuming that the masses of the primary and secondary components are $M_1 = 1.1$ $M_\odot$ and $M_2 = 1.0$ $M_\odot$ (according to Harmanec 1988) respectively, minimal mass of the third body results in 0.65 $M_\odot$. Such a component could be probably detectable in the light curve solution and also could be evident in the spectrum of the system, but no such attempt has been carried out so far. Its photometric distance results in approximately 250 pc, and therefore the predicted angular separation is about 75 mas, while the magnitude difference from the EB is about 2.8 mag. A detection of such a component is hence near the limits of the current interferometric techniques.

3.6. AH Tau

AH Tau is an eclipsing binary of W UMa-type, its apparent brightness is about 11.4 mag in V filter, its orbital period is about 0.33 days and the spectral type was classified as G1p (Brancewicz & Dworak 1980). The first photographic light curve was observed and briefly ana-
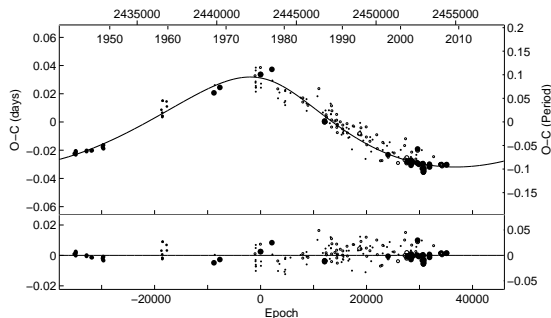
FIG. 8.— The $O - C$ diagram of AH Tau (upper part), where the solid line represents the theoretical LITE variation caused by a 3rd body and the $O - C$ residuals obtained after the subtraction of LITE (lower part). For the explanation of symbols see Fig.1.

lyzed by Binnendijk (1950). The most detailed analysis of its light curve was presented in Liu et al. (1991), resulting in a set of basic physical parameters.

A period analysis was performed by Yang & Liu (2002), who also noticed variable period changes and they concluded that their existence was due to the magnetic activity, the mass loss and the radius swelling of the components. Our new data set consists of more data points (204 times of minima). The final $O - C$ diagram fitted by the theoretical curves is displayed in Fig.8 and the final LITE parameters are given in Table 3. The parabolic curve due to the steady period decrease could not fit very well the most recent data points, but LITE hypothesis is able to describe also the behavior of the newest observations.

The LITE parameters lead to the predicted value of the third mass, resulting in 0.51 M$_\odot$. Contribution of such a body could be observable in a precisely measured light curve of this system. Liu et al. (1991) also derived a photometric parallax of this system, resulting in a value of 281 pc, which yields the predicted angular distance of such body of about 83 mas, which is within the limits for the modern stellar interferometers. On the other hand, the magnitude difference between the third component and the eclipsing pair is about 3.7 mag, which is too high to expect such a body to be discovered.

3.7. *Alternative explanation of the orbital period changes*

The O-C residuals show additional non-periodic variations in the $O - C$ diagrams, which cannot be described by applying only the LITE hypothesis. The residuals in Figs. 1 to 8 show also additional variations with variable periods and amplitudes much lower than that of LITE. These could be caused by the presence of stellar convection zones, in an agreement with the so-called Applegate's mechanism, see e.g. Applegate (1992), Lanza et al. (1998), or Hoffman et al. (2006). Such an effect could play a role, because the spectral types of many of the components are later than F5 (see Zavala et al. (2002) for a detailed analysis). To conclude, for a better description of the observed period variations of these systems, the magnetic activity cycles could be present together with the LITE. On the other hand, one has to take into consideration that the spectral types of most of these binaries were not derived from their spectra, but only on the basis of their photometric indices and therefore are not very reliable.

The only system, where one could estimate the variation of the quadruple moment (see Applegate 1992) required to explain the long-term period variations, is AH Tau, where the semi-major axis of the orbit from the light curve solution is known. Using the following equation

$$\Delta P = A\sqrt{2(1 - \cos\{2\pi P/p_3\})}$$

(Rovithis-Livaniou et al. 2000) one could compute the amplitude of the period oscillation. The period variation $\Delta P/P$ can be used for calculating the variation of the quadruple moment ΔQ, using the equation (Lanza & Rodonò 2002)

$$\frac{\Delta P}{P} = -9\frac{\Delta Q}{Ma^2}.$$

This quantity results in $\Delta Q = (6.20 \pm 0.60) \cdot 10^{49}$ g·cm^2, which is not inside the limits for active binaries (range of values from 10^{50} to 10^{51} g·cm^2) and therefore the variation in AH Tau could not be explained by this mechanism.

4. DISCUSSION AND CONCLUSIONS

Six contact eclipsing binaries were analyzed for the presence of LITE on the basis of their $O - C$ diagram analysis and the times-of-minima variations. A few new observations of these systems were obtained and used in the present analysis. All of the studied systems show apparent changes of their orbital periods, which could be explained as a result of a third component orbiting the EB around their common center of mass.

Such a variation has usually a period of the order of decades, as one can see from Figs.1–8, which can be described by applying the LITE hypothesis sufficiently. In the case of FZ Ori the quadratic term in the light elements was also used. This could be explained as a mass transfer between the two components, which is a common procedure in contact systems. The conservative mass-transfer rate was calculated.

Regrettably, in most of the above systems no detailed analysis (neither photometric nor spectroscopic) has been made so far. The spectral types and the masses of the individual components in the systems are only approximate, so the parameters of the predicted third bodies are also affected by relatively large errors. Due to missing information about the distances to these binaries, we have used a photometric parallax for the distance determination and therefore also the predicted angular separations of the third components could be estimated. It is obvious that only further detailed photometric, as well as spectroscopic and interferometric analysis would reveal the nature of these systems and confirm or reject the third-body hypothesis.

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